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A Service Learning Structural Engineering Capstone Course and the Assessment of Technical and Non-technical Objectives

DAVID W. DINEHART and SHAWN P. GROSS
Department of Civil and Environmental Engineering
Villanova University

ABSTRACT

The primary role of a civil engineer is to serve the community; thus, it is essential that students understand the impact of engineering projects on, and the context of engineering projects within, society. One goal of an engineering capstone design course should be to mesh the technical knowledge of the discipline with an encompassing engineering problem that incorporates “real world” issues and challenges. With all of the aforementioned criteria in mind, the objective of Villanova University’s structural capstone course described herein is to integrate technical and non-technical issues through a challenging real world project. This paper presents the development, implementation, objectives, and assessment of a structural engineering capstone course that incorporates an international service project. All data indicates that the students participating on the service trip achieve significantly higher non-technical outcomes compared to those students that work solely on the design project.

Keywords: Service learning, capstone, structural engineering, learning objectives, assessment

INTRODUCTION

Engineering capstone courses are often an integral part of an ABET accredited program. As evidenced at the National Capstone Design Course Conference in June 2007 at the University of Colorado at Boulder, the pedagogy of teaching capstone courses is very diverse (Todd et al., 1995, Dutson et al., 1997, Howe, 2007). Some universities have dedicated faculty to teach capstone, while others involve all faculty members. Many schools have established programs where 100 percent of the projects are externally funded, and many more programs are attempting to move to this model to have students solve real problems while generating revenue for their college (Jones, 2007, Zable, 2007).

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At the other end of the spectrum there has been an increase in the number of service related capstone projects aimed at helping local communities and those without the financial resources to procure engineering services (Martin and Haque, 2001, Dekker et al., 2007). The nature of the service projects is also very diverse. Many projects have focused on providing technical solutions to the needs of local communities (Padmanabhan and Katti, 2002, Grisso et al., 2007), while many look to aid individuals in Third World countries around the world (Silliman and Ketchum, 1998.)

The current generation of students seems to have a passion for answering the call to serve a global population, as evidenced by the popularity and growth of organizations such as Engineers Without Borders (EWB) and Engineers for a Sustainable World (ESW). In fact, there are universities that partner their capstone efforts with those of their EWB sections (Aidoo, 2007, Bielefeldt, 2007). There are more fundamental needs within the Third World, such as providing clean water, safe housing, and education, than the entirety of capstone courses in our university system can solve (Johnson et al., 2007). The benefits of service projects are many, but one of note is the fulfillment of both technical and non-technical learning objectives.

There is also the omnipresent need for assessment of objectives for capstone courses. This is often a challenging endeavor for technical learning in project based courses and can be even more difficult for non-technical objectives. Typical instruments include evaluation of student work, rubrics for specific objectives, and student surveys (Beyerlein et al., 2007). It is also clear that there is no one-size-fits-all model for capstone courses or the assessment of learning objectives. Each course (and assessment strategy) must be tailored to fit the curricula needs of the department and college within the educational mission of their university.

The mission of Villanova University includes developing an environment in which students may experience a Christian intellectual and moral perspective. A medium-sized comprehensive university, founded by the Augustinian Order of the Roman Catholic Church, Villanova University emphasizes undergraduate instruction and is committed to a strong liberal arts component in each of its degree programs, including engineering. The University is committed to the development of well-rounded students and has a strong service culture. Hundreds of students, faculty, and staff participate in extracurricular service activities including week-long mission trips over spring, summer, fall and winter breaks, and the University has a number of service learning opportunities embedded within its curricula.

This paper discusses the development, implementation, objectives, and assessment of one of those opportunities—a service learning capstone course in structural engineering offered by the Department of Civil and Environmental Engineering. Civil Engineering Design Project II (CEE 4606) is a team-based design course that serves as the capstone course for the undergraduate curriculum. Students work on a comprehensive design project in one or more of the department's five specialty areas: environmental, geotechnical, structural, transportation, and water resources. In the structural

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engineering specialty area, the design project has included a service learning component since 2000 and a one credit service learning course (CEE 4611) that parallels the capstone course.

DEVELOPMENT

One of the poorest countries in the Western Hemisphere, Honduras is a country still trying to recover from decades of guerilla warfare, and has an overwhelming number of children whose parents are unable to provide for them. Amigos de Jesus (Friends of Jesus) is a Catholic orphanage that offers a refuge for abandoned and abused boys in a remote area of Western Honduras. The orphanage was co-founded in 1997 by Sister Teresita, S.S.N.D., a Honduran nun, Reverend Dennis O' Donnell, a Catholic priest, and Anthony and Christine Granese, a 1990 Villanova Civil Engineering alumnus and his wife. The mission of the orphanage is to provide boys the opportunity to grow up in a loving environment where they will receive a formal education and a lifelong skill such as farming, welding, or carpentry.

In late December 1999, Anthony Granese approached the College of Engineering with the idea of developing a relationship with the orphanage. At that time, work on a two-story reinforced concrete structure to house the six children and the two administrators was nearing completion, and construction of a dormitory structure had been initiated. The idea of building a reinforced concrete cross on a hill overlooking the orphanage was discussed. The cross would serve as a symbol of hope for the boys and the surrounding villages in the valley. The structural engineering capstone course seemed to be a natural fit for the scope of the design needs of Amigos de Jesus. Consequently, plans were made to focus the 2000 course around the design and construction of a 25-foot tall reinforced concrete cross. The selection of this project in a Third World country offered the students some interesting design challenges, tied directly to the University's Catholic mission, and provided the feasibility of being constructed in one week. Photographs of the final concrete being placed via buckets and the final product are shown in Figure 1.

Student feedback regarding both the technical and non-technical learning from the cross project in 2000 was overwhelmingly positive as seen in this quote from a student on that trip.

"From an engineering standpoint, it was extremely valuable. Normally, you would work on engineering-related projects and that's where it stops. You never get to see things take physical shape. The construction helped us better understand what we were doing and made us realize what kind of considerations you might never have thought of if you did only the design work. The personal side of the experience was by far the most valuable part of the trip. The work we were doing was something that had value in the real world. Traveling to a country far different from our own, and working with people so different from others whom we deal with everyday, was a unique experience."

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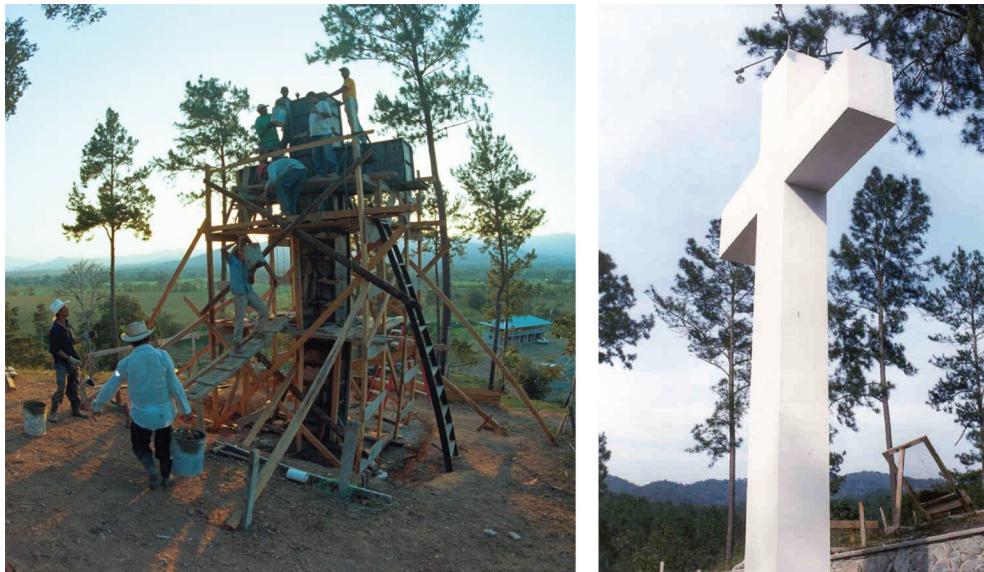


Figure 1: The concrete cross during construction and as it looks today.

Consequently, it was decided that the partnership between Villanova and Amigos de Jesus would continue. The 2001 through 2003 capstone projects focused on the design and construction of a split-level volunteer center and chapel. The students were given some rough architectural sketches to aid them in developing their final designs. Progress on this three year project is shown in Figure 2.

From 2004 through 2007 students surveyed a site, developed designs, and aided in the construction of an eight building elementary school complex. The construction of the school complex has been supervised by two different Villanova University civil engineering graduates that volunteered for long term service at the site. When completed, the complex will include an administration building, three classroom buildings, a computer laboratory, two special use buildings for science, music, and art classes, and a restroom facility. The school opened in 2006 when the administration building and one classroom were completed. The school not only serves the boys living at Amigos de Jesus, but the boys and girls of the surrounding community as well. Figure 3 shows the architectural rendering the students were given as a starting point for the classroom building and a photo taken on the first day of school. Figure 4 shows a view of the school in the spring of 2007. Currently, all designs for the school complex are finalized and five buildings are operational.

In an effort to broaden the impact on the surrounding area, Amigos de Jesus recently decided to open their doors to young girls in need. Consequently, the 2008 structural engineering capstone

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Figure 2: The volunteer center/chapel from foundations to completion.

project was the design of a new girls' dormitory. The students submitted their completed designs in May 2008. A link is provided to view a [virtual tour](#) of the final design.

IMPLEMENTATION: CEE 4606 – CAPSTONE DESIGN

The capstone course (CEE 4606) at Villanova University is structured to allow groups of between three and five students to complete a design that solves a “real-world” engineering problem over the course of one semester. This three credit course is offered in the spring semester of senior year and generally has five different sections, each focusing on a civil engineering discipline (environmental, geotechnical, structural, transportation, and water resources). The following is a description of the format and requirements of the structural engineering offering of the course.

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Figure 3: Classroom building from concept to reality.

The class is divided into project groups. The groups act as independent design firms working for the client (the authors serve as the client's representatives). Self selection of the groups is allowed provided that all class members are satisfied with the groups and each group has at least one representative willing to travel to Honduras. The authors have never had to assign the groups. Each group is responsible for the complete structural design, including development of appropriate load magnitudes and combinations, an appropriate analysis, and the design of all beams, columns, foundations, walls, roofs, stairs, and slabs as necessary for the building. The design must conform to the appropriate US building codes to size the structural elements.

The students start the project by interacting with the client to define the design problem and by researching the site in Honduras to develop design criteria such as material properties, building loads, wind speeds, and seismic ground accelerations. They then develop a complete design for the structure. Halfway through the semester, at least one student from each design group travels to Honduras and spends one week at Amigos de Jesus as part of a week-long departmental mission trip. During this time, the site representatives gather additional information from the client to facilitate their design and participate in the construction of one of the structure's elements. The students are required to have a completed design of the structural element (typically a foundation) completed by spring break. This real world need essentially translates to requiring a complete preliminary design of the structure to be finalized in the first six weeks of the semester.

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Figure 4: Bi-lingual elementary school campus under construction.

To maximize the student-faculty interaction during class time, all lectures for the course have been pre-recorded (since 2006). These lectures include background information on the site such as material availability, construction limitations, typical practices, and material properties (determined by previous classes). Recorded lectures also include technical topics that are required to complete the design that are not part of previous courses in the undergraduate curriculum. These lectures include guidance on using the structural codes, lateral load design, connection detailing, and masonry design. A link to examples of one [technical](#) and one [non-technical](#) lecture is provided. Course time is used to meet with the individual design teams and answer their questions and get formal progress reports. Design teams can also request a meeting at any time outside of the scheduled class time.

Five technical progress reports and presentations are required throughout the semester. Each group member is responsible for presenting at least one progress report. The final submittal includes a technical report with all calculations, a complete set of engineering drawings in both English and Spanish, and a presentation to faculty, professional engineers, students, and parents. The grading for the course is divided between four components: 1. Individual Grade (20%), 2. Progress Reports and

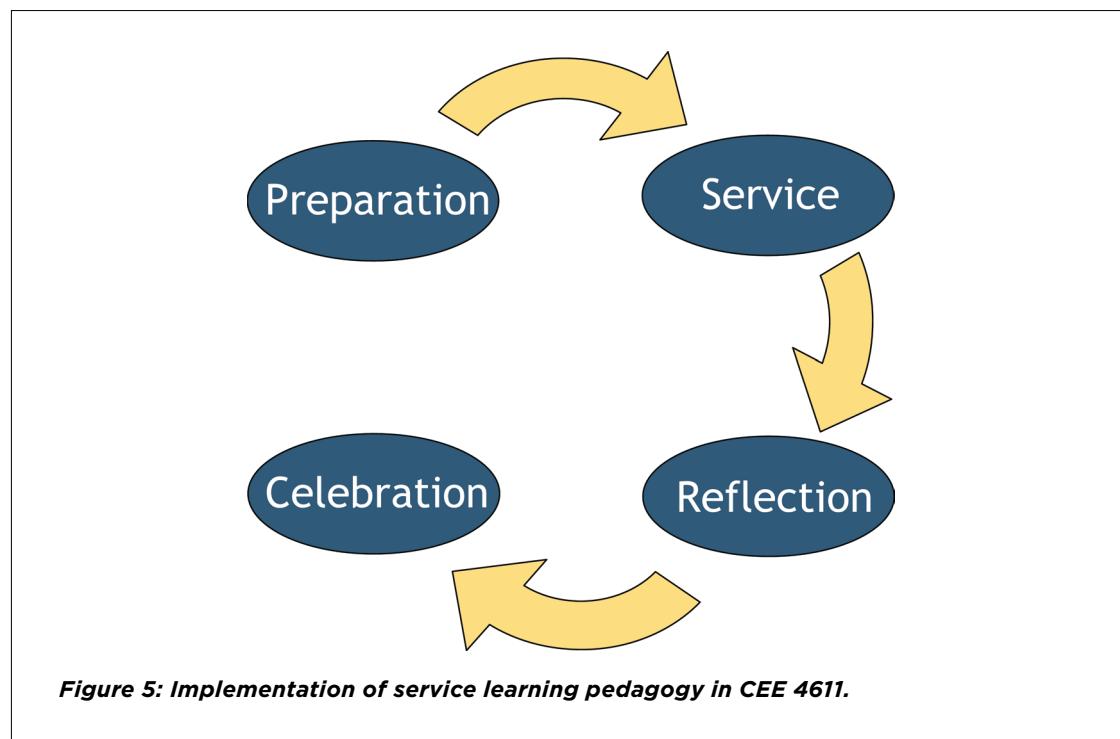
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Presentations (30%), 3. Final Presentation (20%), and 4. Final Report and Drawings (30%). Group members grade one another at the mid-semester and end of the course; these grades are averaged to determine the individual grade.

IMPLEMENTATION: CEE 4611 – SERVICE LEARNING

Historically, the emphasis of engineering capstone projects has been on technical work. However, the nature of service-oriented design projects allows for the added benefit of non-technical learning. In an effort to further formalize the link between education and service, a parallel one credit service learning course, CEE 4611, was introduced in 2003 for all students participating on the Honduras trip. The course meets one hour per week (in addition to the trip itself), and is structured around a simple pedagogy of service learning that includes four key elements: preparation, service, reflection, and celebration, as shown in Figure 5.

As part of the **preparation** for the trip, students work in groups of two or three and are responsible for conducting background research on Honduras and presenting it to the group. The groups are assigned one topic and get to choose an additional topic of interest. These topics have included politics, geography, history, economics, religion, art, music, etc. Based on the information presented



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by the students the authors host a “Jeopardy” style game show to reinforce their knowledge. Prior to the trip a guest lecturer from the Latin American studies department presents information on Honduras. The final piece of the preparation is the organization of fundraising events. Each student is responsible for paying for their food and travel to Honduras, and students work individually and as a group to raise these funds. The cost of the trip has historically been between \$600 and \$700 per student, depending on airfare, plus the costs of immunizations. In many years the students have raised enough money to cover all expenses, but it is typical for the student to pay between \$200 and \$300 out of pocket.

The **service** provided by the students includes the design work as well as the construction work done in Honduras. A typical construction day begins at 8:00 AM with a lunch break at 12:30 PM. Following an afternoon rest, work resumes at 2:30 PM and continues until 5:30 PM. The students generally spend the final hours of the day playing with the boys. Students are also assigned daily chores of assisting in meal preparation, washing dishes, scrubbing floors, and cleaning bathrooms.

An integral element of service learning is the **reflection** on the service experience. As part of the service learning course students keep a personal journal where specific questions are asked and entries are made prior to the trip, during the trip, and after the trip. A copy of the journal is [provided](#) for review. A web site of the trip activities is also maintained while in Honduras. Students leave daily messages to their family and friends reflecting on the day’s events. Family, friends, trip alumni, and local elementary schools follow the groups’ progress through the week and leave messages for the students. The link to this website is [provided](#) and also contains photos from previous trips. This website is very active the first week of March when followers of the project check for daily updates and leave messages for the students. The day for the children of Amigos de Jesus ends with a group prayer just prior to bedtime to thank God for the gifts they have received. This nightly ritual is a moving experience as boys that have so little compared to us are so thankful for what they have been given. Their prayers of thanks always include that they had food to eat and a place to sleep. The day ends many hours later for the students with a group reflection. Groups of two students plan and lead the reflection. These sessions can last between one and four hours.

The last element of service learning is the **celebration** of the service. The first celebration is during the first class meeting following their return, where the group representatives present to those students that did not travel to Honduras. The guidelines provided by the professors are simple: provide an update of what you learned during the week in Honduras. Every year the Honduran travelers provide their classmates with a thorough presentation. Inevitably the presentation is relatively brief in regards to the technical update on their designs and the construction progress report, and the vast majority of the presentation focuses on the non-technical aspects of the trip such as having to cross a river on foot when going to church in town, playing soccer with the boys, discussing

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the beauty of this poverty stricken country, or how gracious their hosts were. Most students find it challenging to fully describe the essence of Amigos de Jesus and the full impact of their week of experiences in Honduras.

The main deliverables for the service learning course are the creation of two posters and one oral presentation. Students work in groups to create one poster focusing on the construction work ([technical](#)) and one focusing on the relationships developed with the boys ([non-technical](#)). Links to the two posters have been provided. Additionally, a presentation is prepared on the non-technical aspects of the trip. The trip leaders present at CEE Day, the year end departmental conference that includes technical presentations of all capstone courses and undergraduate research projects. Students are also asked to talk about their experiences at engineering open houses and on-campus high school recruiting events. In addition to these formal celebratory events there are also many planned group social events.

PARTICIPATION

Table 1 presents the enrollment in the capstone course (CEE 4606) and affiliated service learning course (CEE 4611), between 2000 and 2008. The demographic of trip participants is also presented. A typical trip might include two faculty members, six seniors, and four underclassmen interested in structural engineering and/or service. The authors have participated in all trips. Graduate students and alumni that have previously been to the site have served as mentors on trips as well. Overall about 42% of all CEE seniors have enrolled in the structural engineering capstone section, and one-third of these students have elected to go to Honduras. Approximately 58% of the students who go on the trip and enroll in the CEE 4611 service learning course are also enrolled in the CEE 4606 capstone course, with the remainder being other seniors, juniors, or sophomores. A significant portion of the sophomores and juniors who participate on the trip will return to Honduras with their own graduating class when they become seniors.

ASSESSMENT

In order to focus the teaching strategies within the capstone (CEE 4606) course, a list of eight technical and eight non-technical objectives were developed in 2001. These objectives are listed in Table 2. Many of these objectives coincide with the attributes that are required for ABET and ASCE accreditation. A [survey](#) was developed and is given to all students enrolled in CEE 4606 in order to

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Semester	Total CEE Seniors	Seniors enrolled in CEE 4606	Students enrolled in CEE 4611	Went to Honduras							
				TOTAL	Faculty	Graduate Students	Seniors enrolled in CEE 4606	Other Seniors	Juniors	Sophomores	Alumni
Spring 2000	39	7	N/A	10	2	0	4	0	4	0	0
Spring 2001	40	18	N/A	11	2	0	6	1	2	0	0
Spring 2002	45	25	N/A	15	2	3	5	0	4	0	1
Spring 2003	51	25	10	13	2	0	7	0	3	0	1
Spring 2004	39	14	11	14	2	0	3	2	5	1	1
Spring 2005	33	15	10	15	4	1	5	0	5	0	0
Spring 2006	48	18	9	12	2	1	4	0	5	0	0
Spring 2007	41	15	10	13	2	1	6	0	4	0	0
Spring 2008	52	27	16	18	2	0	13	0	3	0	0
TOTAL	388	164	66	121	20	6	53	3	35	1	3

Table 1: Course enrollment and trip participant descriptions.

formally measure how well the course satisfies the objectives of both the technical and non-technical elements of the course. The survey was adapted from Eyler et al., 1999. To date, eight years of data has been generated and collected.

The survey is administered as a requirement at the end of the capstone course, thus the rate of return is extremely high. In all, 94% (147 out of 157) of students enrolled in the course completed the survey. Note that the survey data does not include students such as juniors who only enrolled in the service learning course but were not part of the capstone design course, nor does it include seniors from 2000 since the survey was first administered in 2001. The data is presented in Table 2, and is shown separately for students who went to Honduras and students who did not go to Honduras. The survey scale ranged from 1 to 5, with 1 defined as the objective not being satisfied at all and 5 defined as the objective being satisfied very well.

The data for technical objectives is presented graphically in Figure 6, which show the annual mean response for the eight technical objectives combined. The annual mean responses for the eight individual technical objectives are presented in Figure A-1 in the Appendix. The figures clearly show that the technical objectives are being satisfied very well by all students participating in the capstone course. In fact, the mean response for all eight technical learning objectives is higher than 4.00. Though the overall scores have always been relatively high, a slight improvement over the first three to four years can be seen, during which time the format of the course was being refined by the authors.

Further evaluation shows that for the first four to five years, evaluation scores for all technical objectives tended to be marginally higher for those students that went to Honduras. This indicates that initially, students who went to Honduras felt they learned technical skills better, perhaps as a

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Course Objectives (T = Technical; N = Non-Technical)		Survey Responses ¹			Difference in Means ²
		All Students Surveyed (n = 147)	Students Who <u>Did Not</u> Go to Honduras (n = 102)	Students Who <u>Did</u> Go to Honduras (n = 45)	
T1	In this course, I was able to synthesize and apply previous coursework in Structural Engineering.	4.41 (0.68)	4.35 (0.73)	4.56 (0.55)	<u>0.20</u>
T2	In this course, I developed a better understanding of how different components of a structure fit together.	4.46 (0.72)	4.42 (0.76)	4.56 (0.62)	0.13
T3	In this course, I developed a better understanding of how real world constraints (cost, scheduling, material availability, etc.) affect a structural design.	4.24 (0.85)	4.21 (0.85)	4.33 (0.85)	0.13
T4	In this course, I was able to develop a professional work ethic.	4.05 (0.82)	4.00 (0.88)	4.16 (0.67)	0.16
T5	In this course, I was able to practice technical presentation skills, including presentation of technical drawings, calculations, reports, and oral presentations.	4.60 (0.60)	4.58 (0.65)	4.64 (0.48)	0.07
T6	In this course, I was able to further my problem solving skills.	4.33 (0.69)	4.31 (0.69)	4.38 (0.68)	0.07
T7	In this course, I was able to function as part of a team and work on teamwork skills.	4.56 (0.68)	4.55 (0.64)	4.60 (0.78)	0.05
T8	After taking this course, I feel more competent entering the work force as a Structural Engineer.	4.27 (0.82)	4.20 (0.91)	4.44 (0.55)	<u>0.24</u>
N1	After taking this course, I am more aware of global issues.	3.63 (0.90)	3.43 (0.86)	4.09 (0.82)	<u>0.66</u>
N2	After taking this course, I am more likely to become involved in service-related activities.	3.50 (1.12)	3.16 (1.06)	4.27 (0.84)	<u>1.11</u>
N3	After taking this course, I feel that I am a more well-rounded individual.	3.73 (0.96)	3.50 (0.93)	4.27 (0.81)	<u>0.77</u>
N4	After taking this course, I feel better about myself.	3.76 (1.02)	3.56 (1.06)	4.22 (0.77)	<u>0.66</u>
N5	After taking this course, I have a better understanding of myself.	3.44 (1.19)	3.15 (1.16)	4.11 (0.96)	<u>0.96</u>
N6	After taking this course, I have a better understanding of others.	3.81 (0.96)	3.56 (0.96)	4.38 (0.68)	<u>0.82</u>
N7	After taking this course, I feel more spiritual.	2.76 (1.28)	2.35 (1.09)	3.69 (1.18)	<u>1.34</u>
N8	After taking this course, I feel a sense of accomplishment.	4.56 (0.74)	4.47 (0.80)	4.76 (0.53)	<u>0.28</u>

¹ Mean response reported, with sample standard deviation in parenthesis [1 = Not Satisfied at All, 2 = Satisfied Only a Little Bit, 3 = Satisfied Adequately, But Room for Improvement, 4 = Satisfied Reasonably Well, 5 = Satisfied Very Well]

² Underlined bold typeface indicates difference in means that is statistically significant to 90% confidence level.

Table 2: Technical course objectives and post-course survey results.

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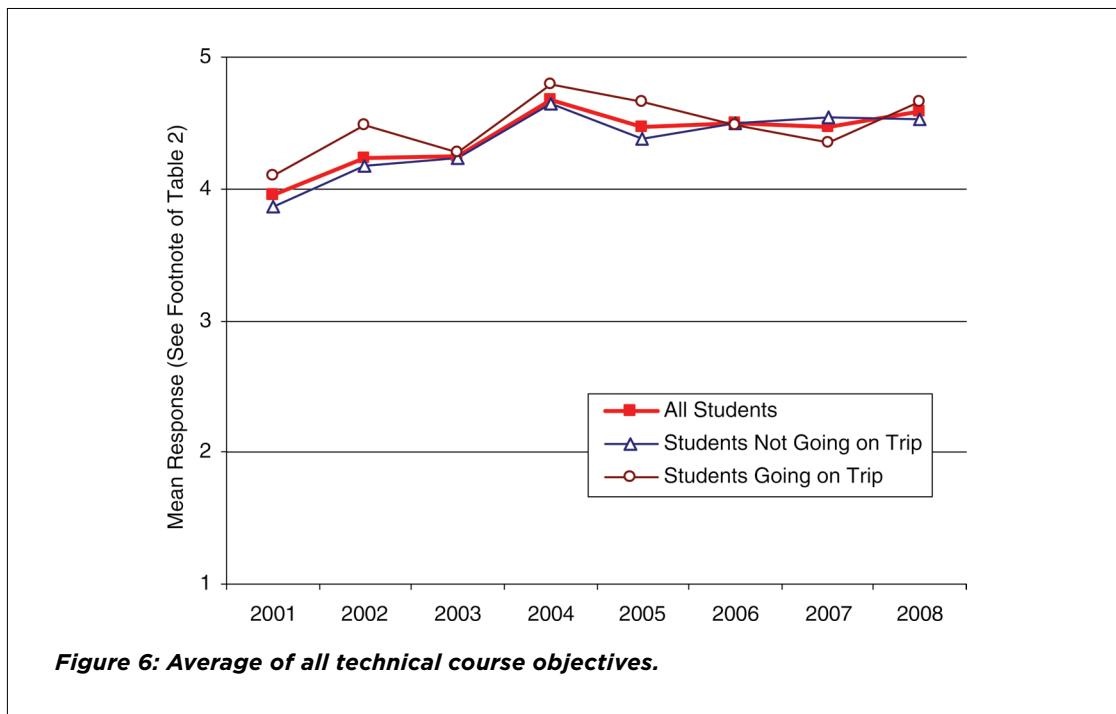


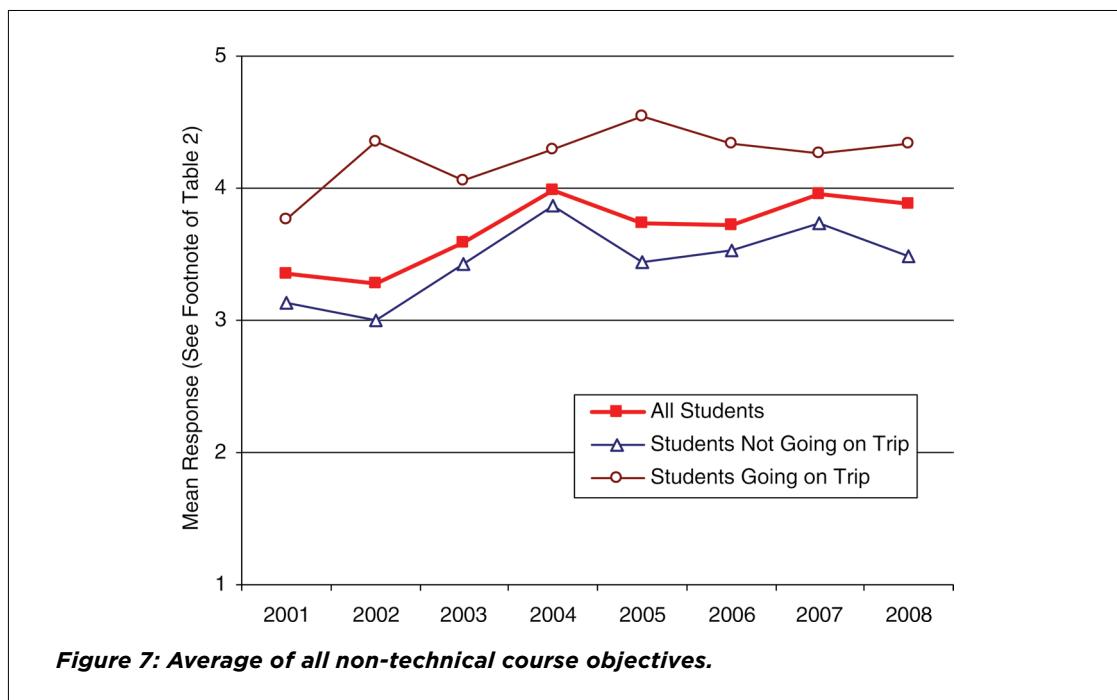
Figure 6: Average of all technical course objectives.

result of the hands-on work on site and direct interaction with the clients while in Honduras. However, in later years the scores tend to be very similar or in some cases even higher for students that did not travel to Honduras.

Figure 7 presents the mean responses for the non-technical course objectives. Figure A-2 in the appendix shows the data broken down by individual objective. It is evident that while the non-technical objectives are on the whole rated lower than the technical objectives, they are still rated as “adequately satisfied” by all students (indicated by a score of 3 out of 5). Only non-technical objective N7 related to feeling more spiritual failed to reach a rating of 3 in recent years. On the other hand, nearly all students leave the capstone experience feeling a sense of accomplishment as a result of applying their engineering education in a comprehensive project with a service element (Objective N8).

As might be expected, the figures clearly show that the students that participate on the trip feel that these non-technical objectives are satisfied to a significantly higher degree than do the students that do not participate on the trip. This would suggest that while there is a carry-over effect in which students that do not go to Honduras still see some non-technical development because of the nature of the project, the structured one-credit service learning course is vital in developing this non-technical learning to a significant degree. It is worth noting that ratings for non-technical objectives among students have generally increased from year to year, both for students who have gone on the trip as well as for students who have not gone on the trip.

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In order to more formally evaluate the impact of the service learning experience on the technical and non-technical outcomes, the difference in the mean responses of the “Did Go to Honduras” and “Did Not Go to Honduras” student groups is tabulated for each outcome in the last column of Table 2. For all eight technical and all eight non-technical outcomes there is a higher mean score for the group of students who went to Honduras. For all eight non-technical outcomes the difference in the mean is statistically significant at a 99% confidence level, confirming that there is a clear benefit in non-technical learning for the students who go to Honduras. In addition, the differences in the mean are statistically significant at a 90% confidence level for two technical outcomes (T1 and T8) which respectively relate to synthesizing previous Structural Engineering coursework and feeling more competent entering the workforce as a Structural Engineer. The authors suspect that these differences relate to the unique experience in which students are able to construct (and later refine) their own designs (i.e. the transfer of these designs from paper and CAD to real life).

An important outcome not captured by the data is that to date there have been five civil engineering graduates that have volunteered for long-term (one year or longer) work assignments at the site. These students supervise construction, teach English, and coordinate ongoing student design efforts, while living in a volunteer center that they designed and built. A 2008 graduate is currently onsite and will initiate the construction of the girls’ dormitory at the end of 2008. Additionally, numerous other alumni of the course have participated in long-term service activity

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immediately after graduation, many of which allowed them to apply their engineering skills to better serve society.

CONCLUSION

The stated mission of the Department of Civil and Environmental Engineering is to provide students with a high quality, contemporary, broad-based, civil engineering education within a Judeo-Christian, humanistic context. The unique structural engineering capstone course described in this paper builds on the inherent service-oriented nature of the civil engineering profession in a manner that is consistent with the Department and University's mission and culture of service.

The technical challenges for this course include those typical of most real-world projects: design constraints, building code compliance, schedules, and final deliverables. The nature of this project including the client being from a rural area in a Third World country provides many additional real challenges: extreme financial constraints, unknown material properties, design requirements for an active hurricane and seismic region, and communication of the final product in a foreign language. Following successful completion of this project, students understand how a structural design takes shape and the professional responsibilities that go along with it. They can work successfully in teams and present their technical outcomes. Data shows that even students that did not travel to Honduras feel well prepared to enter the workforce as a structural engineer at the conclusion of this course.

The project and associated trip serve as an important means toward exposing our students to important issues, issues more important than the technical ones that they have learned in the process. Clearly, the non-technical benefits of this project are numerous. As demonstrated by the survey data collected over the last eight years, this capstone course has fostered a learning environment where students are able to simultaneously apply their technical skills, directly serve others in need, and continue their own personal development and growth as members of a global community.

NOTE FROM THE AUTHORS

The last ten years has been a labor of love for the authors, and we have reaped far more rewards than we could have imagined; however, it has been a great labor nevertheless. We challenge University, College, and Department administrators to encourage, support, and foster their faculty members to develop similar experiences for their students. Ask yourself the following questions: How would this work be valued in your academic environment? How would it be valued in the rank and tenure

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process? Would you rather have a junior faculty member write a journal paper and give a presentation at a conference or develop a course like this? We would submit that the development of this program has served our traditional scholarly research program far more than getting an industry or government grant would have, but that is a topic for another paper.

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BIOGRAPHICAL SKETCH OF AUTHORS

David W. Dinehart is a Professor of Civil and Environmental Engineering at Villanova University, Villanova, PA. He earned a BSCE and MSCE from Bucknell University in 1990 and 1991, respectively. He earned a PhD from the University of Delaware in 1998, following a few years of designing power facilities for Bechtel. His research interests include the design of castellated and cellular steel beams, the design and behavior of open web steel joists, and the seismic evaluation of wood structures. He is a member of ASEE, ASCE, and AISC.

Shawn P. Gross is an Associate Professor in the Department of Civil and Environmental Engineering at Villanova University, Villanova, PA. He earned a BSE from Tulane University in 1993, following which he pursued graduate studies at The University of Texas, Austin where he earned an MSE in 1995 and a PhD in 1998. His research interests include the design and behavior of reinforced and prestressed concrete structures, including the use of high strength concrete and FRP reinforcement, and the design and behavior of open web steel joists. He is an active member of ACI and is a voting member of numerous committees and a member of ASEE and ASCE.

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APPENDIX A

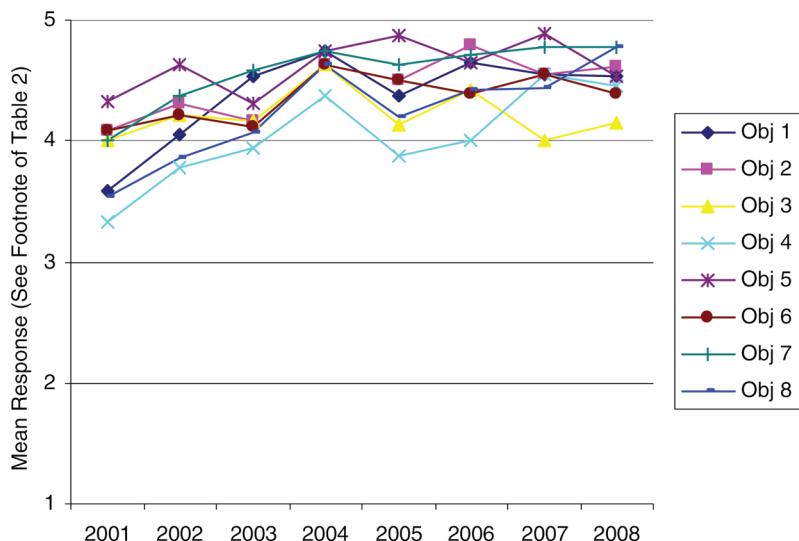


Figure A-1.a: Individual technical objectives for students not going on trip.

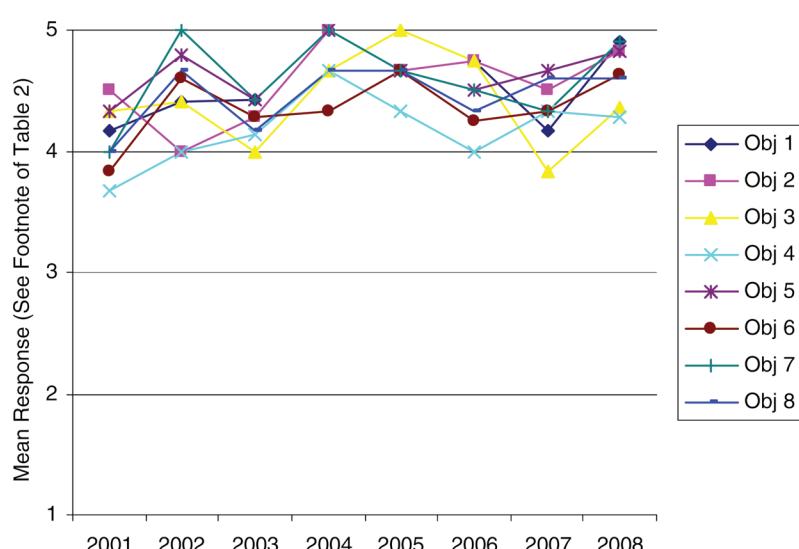


Figure A-1.b: Individual technical objectives for students going on trip.

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